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Non-linear Based Hybrid Denoising filter for Alzheimer's disease Magnetic Resonance Imaging

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***Abstract*—** Noise is a natural property of medical imaging, and it commonly tends to diminish the image resolution as well as contrast, thus dropping the diagnostic rate of this imaging modality, there is a developing attentiveness in using noise reduction techniques in a variety of medical imaging applications. This paper presents a hybrid nonlinear filtering algorithm in which the proposed method has two stages. In the first stage, the rank-ordered sequence is used to decide whether a pixel is corrupted or not based on a decision measure which considers the differences of adjacent pixel values in the input image. In the second stage, the replacement is done by the weighted median value of uncorrupted pixels in the filte1ing window. The visual and experimental results show that the proposed filter can provide very high quality restored images with image detail preservation for various level noise density images.

***Keywords*—** Alzheimer's disease, Denoising, MRI, Non – linear, Median filter

I. INTRODUCTION

Currently, a fast development in engineering science and Medical Instrumentation has assisted the improvement of digital medical imaging. Noise removal is the most important challenging preprocessing in the medical image processing system. Impulse noise is often introduced into images during acquisition and transmission, has undesirable effects on different image processing purposes. In the occurrence of impulse noise, linear filters are reasonably unsuccessful. Nonlinear filtering techniques are effectively preserved edges and details of images, while methods using linear filters tend to blur and distort them [1]. Accidentally, deserting of ultrasound to attempt to recognize interior organs came while new radiological innovations for brain imaging, for example, magnetic resonance imaging (MRI) were emerging.

This paper proposes the analysis of the efficiency of hybrid Non-linear filtering technique called Decision-Based Weighted Median Filter (DBWF) for removal of salt and pepper noise from gray scale MRI images. The performance of the proposed filtering method is tested with various filtering techniques. Denoising performances are quantitatively measured by Signal to Noise Ratio (SNR), Mean Square Error (MSE) and Structural Similarity Index Measure (SSIM). The experimental results and subjective analysis show that the proposed filter removes the noise effectively for different noise level and it gives the best result for removal of salt and pepper noise. The block diagram of Image filtering system architecture is presented in this paper in Figure 1.

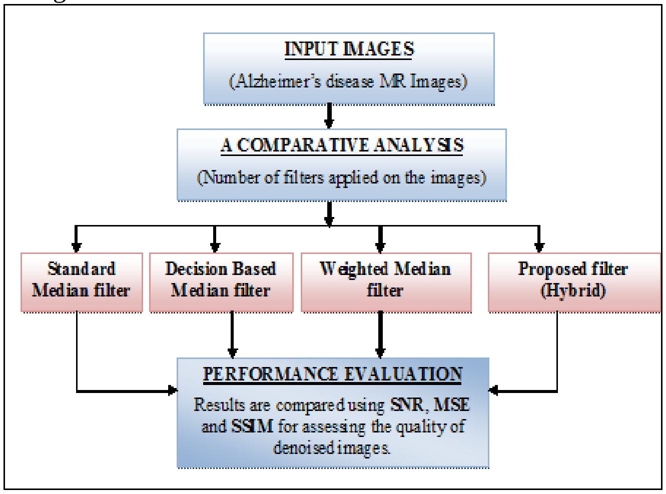


Figure 1: Overall Architecture of the Proposed System

The Rest of the paper is organized as follows, Section I contains the introduction of filtering concept used in MRI Images to find the Alzheimer's disease, Section II contain the detailed view of Alzheimer's Disease, Section III contain the some measures used for denoising Alzheimer's Disease MR Images with Linear Filters, which are Standard Median Filter, Decision Based Median Filter, Weighted Median

Filter and Decision Based Weighted Median Filter, Section IV contains Results and Discussion based on the Evaluation Parameters SNR, MSE, and SSIM, section V concludes research work based on the obtained graphs and results .

II. ALZHEIMER'S DISEASE

Alzheimer's is a vibrant syndrome, where dementia side effects bit by bit intensify over various years. In its beginning periods, memory misfortune is mellow, yet with late-organize Alzheimer's, people lose the capacity to carry on a discussion and react to their condition. It is the 6th pouring cause for death in the United States. Those with Alzheimer's experience a normal of eight years after their indications wind up recognizable to other people, yet survival can extend from 4 to 20 years, contingent upon age and other wellbeing conditions [2].

Alzheimer's has no present treat; however, medications for side effects are accessible and inquire about proceeds. Albeit current Alzheimer's medications can't prevent Alzheimer's from advancing, they can briefly moderate the compounding of dementia side effects and enhance personal satisfaction for those with Alzheimer's and their guardians. Today, there is an overall exertion under the approach to discover better approaches to treat the sickness, postpone its beginning, and keep it from creating.

To better understand how Alzheimer's disease affects the hypothalamus and other regions of the brain, it's helpful to first have an understanding of the primary stages of this progressive disease. The following figure comprises the three stages in image Alzheimer's disease (AD) [3].

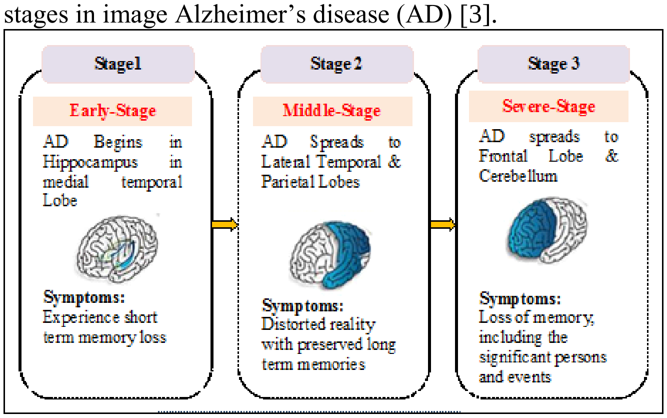


Figure 2: Stages of Alzheimer's Disease

III. DENOISING ALZHEIMER'S DISEASE MR IMAGES WITH LINEAR FILTERS

MR imaging is a popular technique applied in the medical field where the internal organs can be viewed without incursion of human body. Noise happens [3] in MR images amid two stages of procurement and transmission. Denoising methods can be utilized to enhance the image quality as a pre-processing step. It is mainly used to remove the noise that is present and retains the significant information in the input image.

In Image Processing applications, Linear Filters tend to blur the edges and do not remove impulse noise effectively. They do not perform well in the existence of signal dependent noise. Nonlinear filtering has constructed to overcome these limitations. Several classes of nonlinear digital filtering techniques are identified. The significance of the nonlinear filters is that they can be designed and implemented without complex optimization techniques [4]. The various non linear filtering techniques used in this research are described as follows,

A. *Standard Median (SM) filter*

The SM filter is a nonlinear method called as median smoother which endeavors to expel motivation clamor by changing the luminance estimation of the inside pixel of the separating window with the middle of the luminance estimations of the pixels contained inside the window. Despite the fact that the middle channel is straightforward and gives a sensible commotion expulsion execution, it evacuates thin lines and hazy spots image points of interest even at low noise densities [5].

The best-known request insights filter is the median filter, which replaces the estimation of a pixel by the middle of the gray levels in the area of that pixel. The definition of median value is listed as follows, A group of numbers: X_1, X_2… X_n, arranged in order of size: $X_{i1} \leq X_{i2} \leq \leq X_{in}$.

$$Y = \text{Median}\{X_1, X_2 \ldots X_n\} = \begin{cases} x_{i(n+1)/2} & ,\text{n is odd} \\ [x_{i(n/2)} + x_{i(n/2+1)}]/2 & ,\text{n is even} \end{cases} \quad \ldots\text{Equ(1)}$$

Where Median {…} expressed the process of computing the median from the sequence $\{X_n\}$, Y indicates this median, which is a neighborhood of a pixel's specific length in a sequence or shape in an image as filtering window [6].

The noisy value of an input image is restored by the center of the filter mask. The pixels in the mask are ranked in the order of their gray levels, and the median of the mask is stored to replace the noisy value in the mask. The median filter output is

$$g(x,y) = \text{med}\{f(x-i, y-j), i, j \in W\} \quad \ldots\text{Equ(2)}$$

In Equation (2), where f (x, y) and g(x, y) are the original image and the output image, respectively. 'W' is a two-dimensional mask, the mask size is n×n (where n is commonly odd) such as 3×3, 5×5, and etc. The median filter effects depend on two things, the size of the mask and the distribution of the noise. The median filter performance of random impulse noise is better than the average filter performance [7].

B. Decision Based Median (DBM) filter

This filter initially formulate the resolution about the pixel is affected by noise/ noise free, and is based on the value of pixel either maximum or minimum in the input image. Pepper noise represented by minimum (0) value and salt noise represented by maximum (255) value. Other than, the middle pixel value is range from 0 to 255 that is considered as a noiseless pixel. So, in this point no need to change anything. When the pixel value occurs in the range 0 to 255, it will be replaced by median rate of existing windowing [8]. This algorithm is described as follows:

ALGORITHM –Decision Based Median Filter

Step 1: choose a 3 by 3 2-Dimension window form input medical image. Let's assume P_{mn} is the current pixel value of the input window.

Step 2: Now Sort every values appear in the present window and split those windows as two categories, such as

X_{mn}= pixels excluding 0 and 255,

Y_{mn}= pixels including 0 and 255.

Step 3: In case of the present pixel rate occurs from 0 to 255 i.e. $P_{mn} \in M_{mn}$, then P_{mn} is a noise free pixel that is leave as it is.

Step 4: If all the values are noiseless, then performing pixel is restored with median value of the current window.

Step 5: If $P_{mn} \in N_{mn}$ and its the adjacent pixels are including the noise values, then increase the dimension of the processing window into 5X5.

i. In current window, the pixel values are not 0 or 255, then obtain the middle value from current window after that restore P_{mn}.

ii. If pixels lie in the processing window, then restore P_{mn} with preprocessed pixel.

Step 6: Shift the window to subsequent element [9].

C. Weighted Median (WM) filter

Weighted median filter is one of the branches of median filter. The operations involved in WM filter are similar to SM filter. The weighted median filter confers extra weight to many pixels during convolution between image and the masking window [10].

$$I = [I_1, I_2, I_3 \ldots\ldots\ldots I_n]$$

$$Y = [Y_1, Y_2, Y_3 \ldots\ldots Y_n]$$

Weighted Median =

$$MED\ [Y_1 * I_1, Y_2 * I_2, Y_3 * I_3 \ldots\ldots\ldots Y_n * I_n] \quad \text{...Equ(3)}$$

Where 'I' represents pixels of the input image and Y represents array of weights. The above equation (3) calculates the weighted median value [11].

D. Proposed Filter - Decision Based Weighted Median filter (DBWMF)

Previous non linear noise reduction approaches work better for fixed valued noises however weakly for uninformed valued noise. Here, we have proposed a Decision based weighted Median filter (DBWMF) method for noise removal from Alzheimer's disease MR Images. It first makes the decision of whether the pixel is corrupted or not. Figure.1 shows flow chart for proposed method.

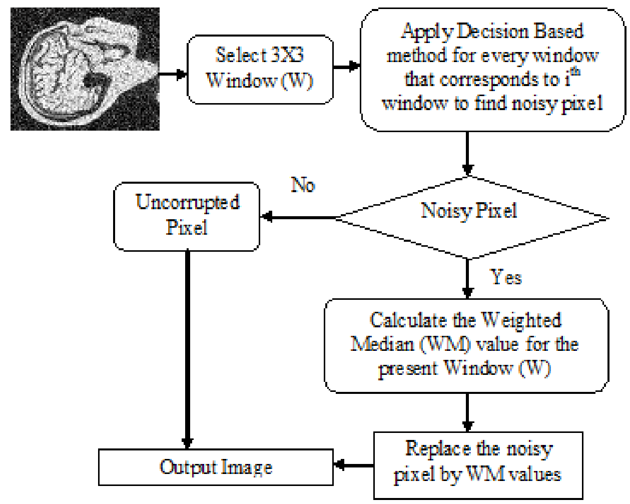


Figure 3: Flow chart for proposed method DBWMF

To identify the corrupted pixel, if the processing pixel satisfies the condition i.e. $0 < Pij < 255$, where Pij is the value of the pixel present at (i,j) position, then it is treated as an uncorrupted pixel and is left unchanged. If the condition fails i.e. if the pixel value Pij has the value 0 or 255, then the pixel is considered corrupted then it is replaced by weighted median value.

In this paper, the proposed algorithm includes two phases: (i) Noise detection over the image by using decision based method to find out the number of noise pixels within the present window (ii) Replace the noise points by the of WM value.

ALGORITHM - Decision Based Weighted Median Filter

Input: Alzheimer's disease MR Image corrupted with noise.

Output: Noise free image.

Process:

Step 1: Select a 3x3 size 2D window. Let's assume that the current processing pixel is P_{ij}.

Step 2: Sort all the pixels present in the processing window and divide them into two group's i.e.

M_{ij}= all the pixel values excluding 0s and 255s,

N_{ij}= pixel values which are 0s and 255s.

Step 3: If the processing pixel value lies between 0 and 255 i.e. $P_{ij} \in M_{ij}$, then P_{ij} is an uncorrupted pixel and it is left unchanged.

Step 4: Calculate the Weighted Median (WM) value for the present Window (W).

Step 5: If all the values are not 0s and 255s, then the processing pixel is replaced with weighted median value after excluding 0s and 255s.

Step 6: If $P_{ij} \in N_{ij}$ and all its neighbouring pixels are containing the value 0 or 255, then increase the size of the window to 5X5.

i. If all the pixels in current window are not 0s and 255s, then take the weighted median value after deleting 0s and 255s from processing window and replace P_{ij}.

ii. If all the pixels in the window are 0s and 255s, then replace Pij with previously processed pixel.

Step 7: Move the window to next processing element.

Step 8: Repeat from step 1 to step 6 until window reaches the last pixel.

IV. RESULTS AND DISCUSSION

It should include important findings discussed briefly. Wherever necessary, elaborate on the tables and figures without repeating their contents. Interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. However, valid colored photographs can also be published.

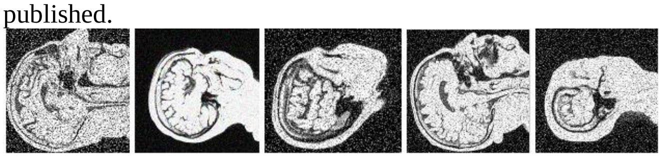
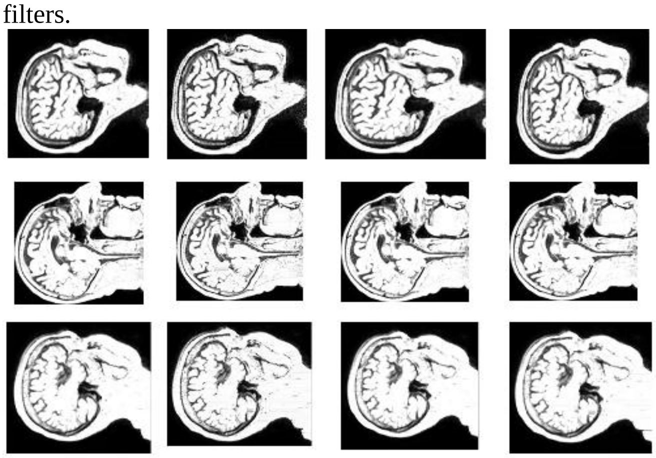


Figure 4: Original image affected with different noise densities

The proposed method evaluated with the quality metrics such as SNR, MSE and SSIM [12] [13] which are widely used for finding statistical computations and performance of noise filters.



(a) (b) (c) (d)

Figure 5: Results of non linear based filters on MR images affected by noise

From the above results it is found that the proposed filter is outperforming in denoising procedures without losing the useful information such as edges and textures. In Fig 4, (a) represents the standard median, the second image (b) represents the DBM, the third (c) represents the WM and the fourth (d) represents proposed DBWMF method. It is evident from these figures that the above denoised images using our proposed method have better visual quality than that using other filters.

Table 1: Comparison of SNR values

Input Images	SM Filter	DBM Filter	WM Filter	Proposed Filter (DBWMF)
Img1	9.8293	9.9678	9.8357	10.0653
Img2	10.4712	10.7071	10.4742	11.0897
Img3	11.7256	11.9987	11.7287	12.1342
Img4	11.9582	12.3981	11.9622	12.7862
Img5	9.7777	9.8761	9.7806	9.9365

Table 2: Comparison of MSE values

Input Images	SM Filter	DBM Filter	WM Filter	Proposed Filter (DBWMF)
Img1	15.9438	15.5632	15.9281	15.1650
Img2	16.5038	16.0949	16.4957	15.9547
Img3	9.0722	8.9760	9.0771	8.4532
Img4	8.6614	8.5291	8.6539	8.0735
Img5	13.9427	13.8321	13.9338	13.7532

Table 3: Comparison of SSIM values

Input Images	SM Filter	DBM Filter	WM Filter	Proposed Filter (DBWMF)
Img1	0.9191	0.9341	0.9191	0.9574
Img2	0.8975	0.9102	0.8975	0.9414
Img3	0.9305	0.9550	0.9370	0.9651
Img4	0.9439	0.9568	0.9463	0.9811
Img5	0.9318	0.9410	0.9325	0.9502

The SNR, MSE, and SSIM [12] [13] values are calculated and a comparison of performance with various filters, namely, SMF, DBMF, WMF and proposed DBWMF filter, are shown in Tables 1–3. The above results and analysis illustrates that the proposed method outperforms over the existing median based filter methods.

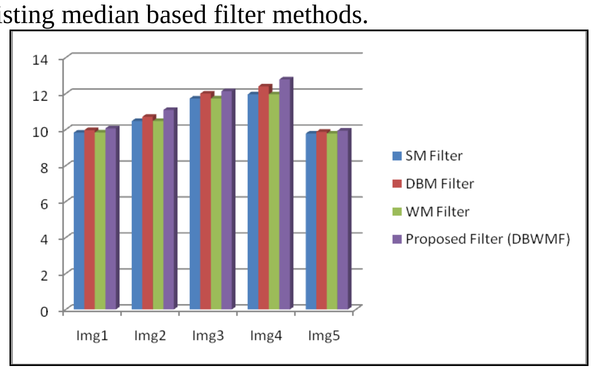


Figure 6: Comparison of SNR values

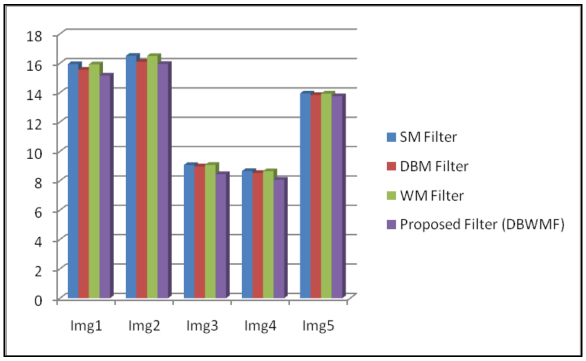


Figure 7: Comparison of MSE values

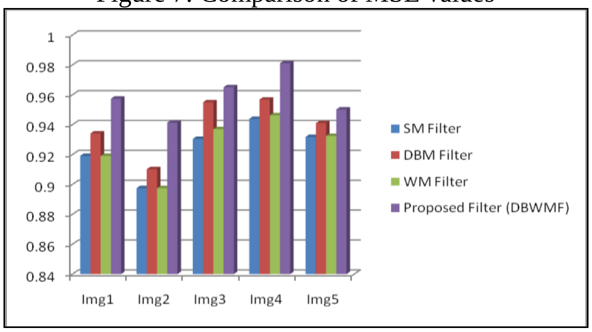


Figure 8: Comparison of SSIM values

The resultant graphs from the Figure 6, Figure 7 and Figure 8, shows that the SNR, SSIM gains and MSE decrease to MR scan images for our proposed technique DBWMF. From the performance evaluation, the proposed method works extremely well for various density of noise is present in the input image.

V. CONCLUSION AND FUTURE SCOPE

Noise removal has been an important research area in medical image analysis. In this paper, a new algorithm (DBWMF) is proposed which gives better performance in comparison with SMF, DBWMF, and WMF in terms of SNR, MSE, and SSIM. The efficiency of the proposed technique is confirmed by the experimental results. Proposed algorithm shows better denoising capability and can also preserve necessary details. The performance of the algorithm has been tested at various noise densities.

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